Ion Exchange at Metal–Ceramic Interfaces

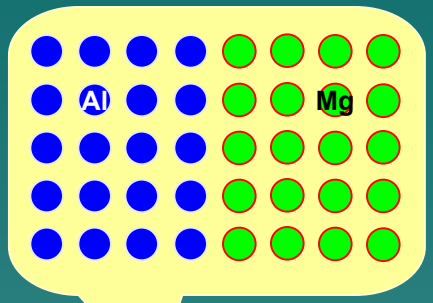
F. Ernst,[1] R. Raj[2]

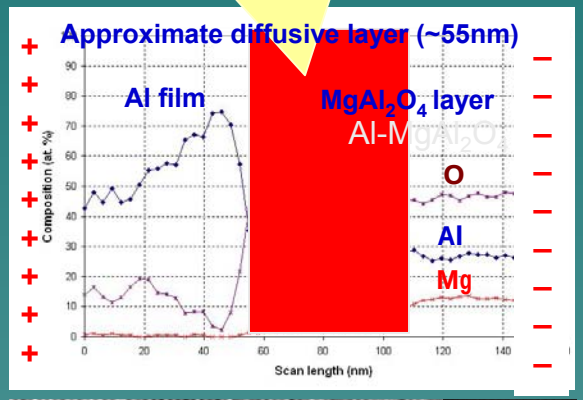
[1]Case Western Reserve University, [2]University of Colorado at Boulder

DMR-0208008

Objectives:

- To study ion-exchange diffusion reactions at planar aluminum-spinel (Al–$MgAl_2O_4$) interfaces.
- To model (and validate) the electrostatic mechanism of mechanical adhesion at such interfaces, and relate it to ion-exchange.

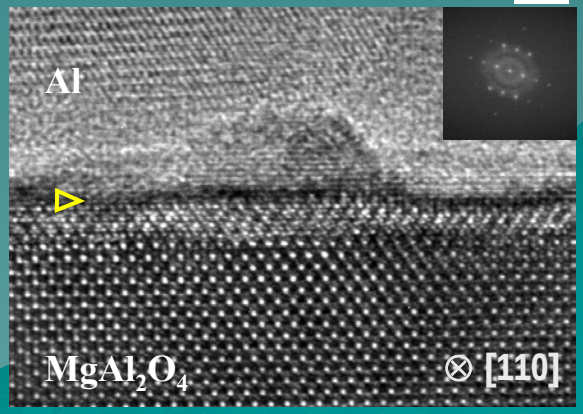




Right: Composition profiles show evidence of enhanced ion-exchange across the interface when annealing in an external electric field.

A New Result:

Tempering aluminum–spinel interfaces in applied *electric fields*, we found credible evidence for diffusion of magnesium and oxygen ions into the aluminum layer, while aluminum diffuses into the spinel layer. The asymmetry in interdiffusion and the difference in the valency of the exchanging ions suggests a correlation between interdiffusion and electrical fields, which is conceptually consistent with the electrostatic model of mechanical adhesion.



Right: High-resolution TEM image revealing structural modification of the spinel layer after annealing in an electric field.

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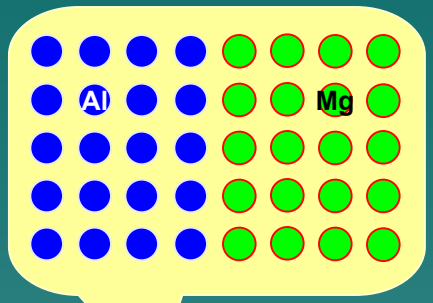

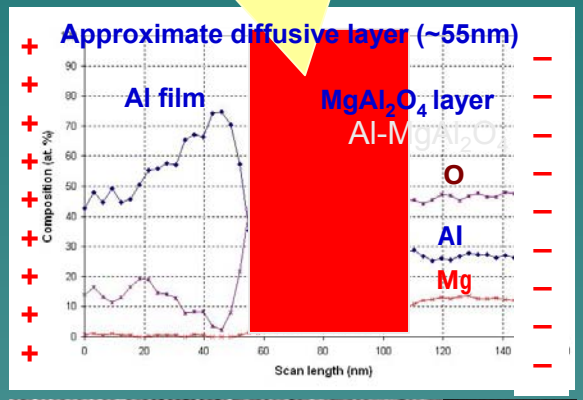

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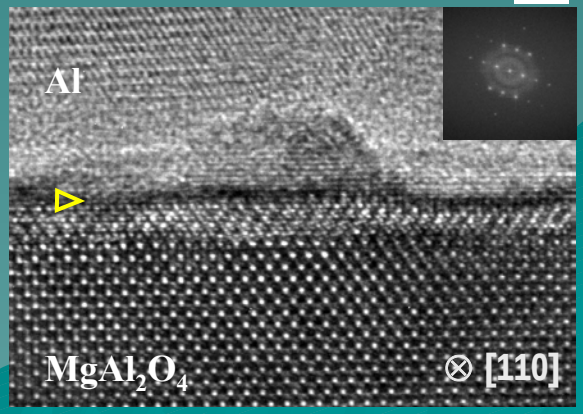

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Education

- **Jeremy Mark**, an undergraduate student supported by NSF's REU program, was trained in UHV technology and has made important contributions to constructing and testing the reactor for annealing in applied electric fields.
- **Brownyn A. Hayworth,** an undergraduate student at CU-Boulder, was trained in oxide thin film growth from precursors and contributed to the 'sample die design' and mechanical tester accessories.
- **Gurpreet Singh**, graduate student at UCB, was trained in UHV techniques, thin-film preparation, and mechanical testing of thin films.
- The graduate students on this project participated in *exchange visits* between our laboratories. **Yeonseop Yu**, graduate student at Case, spent 2 weeks at UCB in 2003. **Gurpreet Singh** spent 2 weeks at Case in 2004. Both visits were very successful in intensifying collaboration and personal relationships.

Broader Impacts

- The latest results of this project were presented at the "Microscopy & Microanalysis Meeting" in Savannah, Georgia, August 1-5.
- A journal article about the effects of annealing under applied electric fields is in preparation.